X-17351

UNCLASSIFIED

N-985

Subject Category: PHYSICS

UNITED STATES ATOMIC ENERGY COMMISSION

PERIPHERAL PRODUCTION IN X PILE

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April 20, 1944

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UNCLASSIFIED

Other issues of this report may bear the number MUC-AMW-36.

Date Declassified: November 23, 1955.

~~Printed in USA, Price 15 cents~~. Available from the Office of Technical Services, Department of Commerce, Washington 25, D. C.

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Proposition

It is proposed to fill the empty channels surrounding the active core of the X pile with thorium carbonate. Three rings of the carbonate would be put around the pile. The inner ring would be not less than 30 cm. from the nearest uranium. The thorium would serve two purposes: the escaping neutrons would produce U^{233} in it and it would protect the concrete by decreasing the neutron flux. The estimated yield of U^{233} is .012 gm/1000 kw day and the thorium would absorb about 50% of the escaping neutrons.

Calculations

The material to be used is a mixture of carbonate, thoria and hydroxide. The estimated composition is

20%	$ThOCO_2 \cdot H_2O$
70%	ThO_2
10%	$Th(OH)_4$

The empirical formula is $ThO_{2.8}\ C_{0.2}\ H_{0.8}$; its molecular weight is 280. Before introducing it into the pile this material would be canned in the regular aluminum cans used for the metal. If the pile is surrounded on three sides by three layers of carbonate this means that approximately 240 channels are filled with 50 cans of carbonate, 12,000 cans in all. This is about three tons of carbonate. This material can be obtained from Lindsay Light which can produce 400 lb. a day with their present facilities.

One of the problems in introducing this material into the pile is that it evolves CO_2 when heated. Enough pressure inside the cans by the CO_2 might rupture them. The solution is to preheat the carbonate at a temperature equal or greater than that which it will have inside the pile. The difficulty then arises that if the carbonate is preheated at too high a temperature its solubility for the extraction process is decreased. Tests show that about 200°C is the highest temperature at which it can be preheated without markedly decreasing its solubility (CC-1024). Hence, the temperature of the carbonate inside the pile must not rise above 200°C.

An indication of how much cooling is necessary to keep the temperature of a carbonate lump below 200°C is that the regular air cooling has sufficed for some cans of thorium carbonate put into the center of the pile. Hence, somewhat less than the regular cooling should suffice for the periphery even at a higher power level than the present one. It is planned to investigate the temperature problem in more detail. (It is also planned to investigate the possibility that the carbonate may decompose under radiation). Until this is done, a reasonable suggestion might be to air cool one out of every three channels in the inner ring and to leave the outer rings uncooled except by conduction to the carbon.

If the canned density of the carbonate is assumed to be 3.52 and if the following atomic cross sections are assumed,

	Th	C	O	H	$ThO_{2.8}C_{.2}H_{.8}$
σ_a	6	.00427	.0015	.3	6.25
σ_t	13.5	4.8	4.2	41.4	59.3

the utilization, p_2, of escaped neutrons can be calculated. The carbonate is first assumed to be uniformly distributed through the cell occupied by the channel in which it is placed. The utilization is then calculated according to the scheme of CP-1350. This p_2 is then corrected for the fact the carbonate is in lumps - using a disadvantage factor calculated for the cell. This disadvantage factor is 1.060.

One might either put the lumps in the closest available empty channels or might leave one or more layers of graphite between the uranium filled center and the thorium filled periphery. The advantage of the latter scheme is that the pile neutrons slow down and the number above the fission threshold is decreased. If the nearest uranium lumps are 20 cm. away, it is estimated that 8.5% of the flux into a thorium lump is of neutrons above 1.2 mev, the fission threshold for thorium. If one layer of empty carbon lattice is left between the thorium and the uranium, that is, if the nearest uranium lump is 40 cm. away, less than 1% of the neutrons are estimated to be above 1.2 mev. As the thorium is put farther from the uranium, the utilization of escaped neutrons decreases. The utilization also depends on the number of layers of the thorium compound:

Utilization of Neutrons Escaping Toward the Sides of Pile

Number of rows	First row of Th 20 cm. from last U row	First row of Th 40 cm. from last U row
1	.405	.299
2	.544	.410
3	.609	.458
4	.640	.482

On the basis of these results, it is recommended that the pile be surrounded by three layers of thorium carbonate at not less than 30 cm. distance from the nearest uranium. At 30 cm., 2.5% of the flux is above 1.2 mev.

The yield of U^{233} can be roughly estimated. The number of fissions/watt is 3×10^{10}. Hence the total number of neutrons leaking from the pile/1000 kw sec

$$= 3 \times 10^{10} \times 2.2 \times 10^3 \times 10^3 \times .05$$

If we assume a utilization of .45 and note that thorium is on only three of the pile's six sides, number absorbed/1000 kw sec

$$= 3 \times 10^{10} \times 2.2 \times 10^3 \times 10^3 \times .05 \times .45 \times \frac{3}{6}$$

$$= .0747 \times 10^{16}$$

number absorbed/1000 kw day of operation

$$= .0747 \times 10^{16} \times 60 \times 60 \times 24$$

$$= 6.43 \times 10^{19}$$

The Pa^{233} produced/1000 kw day of operation

$$= \frac{6.43 \times 10^{19} \times 233}{6.02 \times 10^{23}}$$

$$= .0249 \text{ gms.}$$

If an efficiency of 50% is assumed for the separation process, the yield of U^{233}/1000 kw day of operation is .0124 gms.

Pa^{233} decays with a mean life of 39.6 days. The amount of Pa^{233} which will be present in the pile after t 1000 kw days of operation

$$= 39.6 \times .0249 \left(1 - e^{-\frac{t}{39.6}}\right)$$

$$= .988 \left(1 - e^{-\frac{t}{39.6}}\right)$$

The amount of U^{233} present is the difference between the amount of Pa^{233} formed and the amount present = $t \times .0249 - .988 \left(1 - e^{-\frac{t}{39.6}}\right)$.

The activity of the material taken from the pile will be the β and γ activity of Pa^{233} and some fission activity. Since the fastneutron flux into the thorium is kept small probably the fission activity can be neglected. The β activity of Pa^{233}/mgm is 20 curies. The reported maximum energy of the β particle varies from .25 to .4 mev. Associated with the β activity are two γ activities, one of the 1.5 mev, $\frac{\gamma}{\beta} = .02$, and one of .4 mev, $\frac{\gamma}{\beta} = .5$.